R E P O R T R E S U M E S

ED 017 008 CG 001 581

SOME EFFECTS OF UNIT STRUCTURE ON ACHIEVEMENT AND TRANSFER.

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PUB DATE 68

EDRS PRICE MF-$0.25 HC-$0.68 15P.

DESCRIPTORS- *SCIENCE COURSES, SCIENCE COURSE IMPROVEMENT PROJECT, *COURSE ORGANIZATION, PROGRAMED UNITS, *COMPARATIVE ANALYSIS, ELEMENTARY SCHOOL STUDENTS, SCIENTIFIC PRINCIPLES, CURRICULUM DEVELOPMENT,

ALMOST NO EXPERIMENTAL EVIDENCE AVAILABLE SUBSTANTIATES THE CLAIM THAT THE BEST POSSIBLE WAY OF TEACHING SCIENCE IS BY BASING THE PRESENTATION UPON THE STRUCTURE OF A SCIENCE. RESEARCH IN THIS AREA HAS BEEN CLOUDED BY THE FAILURE TO CLEARLY SPECIFY THE ORDERED SEQUENCE OF MATERIALS AND INADEQUATE TESTS TO DETERMINE--(1) IF THE DESIRED ORDER EXISTS, AND (2) IF RANDOM ARRANGEMENT OF MATERIALS PRODUCES A DIFFERENT ORDER. IN THE STUDY RELATED HERE, THERE WERE THREE OBJECTIVES. THE FIRST OBJECTIVE WAS TO PRODUCE A SET OF PROGRAMMED MATERIALS WRITTEN TO CONFORM TO A DEFINITION OF ORDER, AND AN ALTERED VERSION OF THESE MATERIALS. THE SECOND OBJECTIVE WAS TO DEVISE MEANS OF DETERMINING IF--(1) THE TWO VERSIONS EFFECTIVELY TAUGHT THE SUBSTANTIVE CONTENT, AND (2) THE STRUCTURED UNIT WAS TRULY STRUCTURED AND DIFFERED FROM THE UNSTRUCTURED UNIT. THE THIRD AIM WAS TO INSTITUTE AN EXPERIMENT WHICH WOULD PROVIDE DATA FOR--(1) MEASURING THE EFFECTIVENESS OF THE TWO UNITS, (2) DECIDING IF THE UNITS WERE STRUCTURED OR NOT, AND (3) EXAMINING SOME EFFECTS OF STRUCTURE ON MEASURES OF TRANSFER AND ACHIEVEMENT. APPROXIMATELY 200 FOURTH, FIFTH, AND SIXTH GRADERS SERVED AS SUBJECTS. THERE IS A FULL DISCUSSION OF THE RESULTS AND OF THE POTENTIAL WORTH OF THE MODELS USED FOR MEASURING THE EFFECTIVENESS AND EXTENT OF STRUCTURE IN THE MATERIALS. THIS PAPER WAS PRESENTED AT THE AMERICAN EDUCATIONAL RESEARCH ASSOCIATION CONVENTION, CHICAGO, ILLINOIS, FEBRUARY, 1968. (IM)

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Presented at AERA Convention
February, 1968; Chicago

Some Effects of Unit Structure on Achievement and Transfer

Since about 1956, there has been a great deal of emphasis on developing new courses for the schools in this country. Much of the energy has been expended in developing new courses in science for the secondary school. The development of these courses is related to a movement to establish new goals for science education in the secondary school. Usually included as a goal is one which is in some way related to what is called the structure of a science. There are several assumptions underlying claims for the advantages of a structured course over other courses, and these assumptions deserve careful attention and consideration. On the basis of these assumptions, it has been asserted that the new science courses offer improvement over existing science courses by

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teaching science in the best possible way - by basing the presentation of science upon a structure of science. Yet there is almost no experimental evidence available to substantiate any such assertion.

Advantages claimed for structured courses frequently relate to motivation, achievement, retention, transfer, and the efficiency with which knowledge can be organized for learning. A pertinent statement of some assumptions upon which claims commonly made must ultimately rest was made by B. O. Smith in the "Introduction" to Education and the Structure of Knowledge (Fifth Annual Phi Delta Kappa Symposium on Educational Research.) The questions posed by treating these as presumptions are self-evident. These assumptions are:

1. That teaching will be more effective if it incorporates the ways elements of knowledge are related logically.

2. That what is learned will be retained longer if it is tied into a meaningful cognitive structure.

3. That what is learned will be more readily transferable if it is tied into a system of knowledge.

4. That the categories of the curriculum - what we ordinarily refer to in conventional terms as subjects - are somehow related to the categories of knowledge and that knowledge can be categorized in ways more conducive to learning than is ordinarily done.

Several studies dealing with the effects of changing the order in which learning materials are presented have been reported. Programmed learning materials were generally used as the medium for instruction, and criterion measures included such variables as achievement, learning rate, retention, and transfer. The ordered sequence has usually been a sequence of learning materials already available and the unordered sequence some random arrangement of these

materials. The results of this research have not provided a clear picture of the effects of altering sequence on criterion measures of learning. In most cases, the confusion is very likely the result of a failure to clearly specify what the ordered sequence of materials is to be and to devise adequate tests to determine if the desired order exists and if a random arrangement of the materials really gives a different order. It will not make sense to consider the effects of a sequence change on any criterion measure of learning until it has first been established that a defined sequence exists and that a change in the sequence has actually been brought about by some alteration of the materials comprising the instructional program.

In the study I am relating here, the first objective was to produce a set of programmed materials which was written to conform to a definition of order and an altered version of these materials. The defined version was called structured, and the definition was that which is encountered

frequently in discussions of structured science courses. A structured unit was written using several concepts of measurement in a way which would result in a development that could be considered hierarchical. This hierarchical arrangement was divided into four sections, and an achievement test was written to be administered at the end of each section. An unstructured version of the measurement unit was obtained from this unit by taking a random sequence of these four sections.

The second objective was two-part: First, to devise a means of determining if the two versions effectively taught the concepts of measurement. A second part was to devise a means of testing the structured unit to see if it was indeed structured and to compare it with the unstructured version of the unit to see if there were detectable differences. The work of Robert Gagné on learning hierarchies provided the ideas for models used in making these two tests. Let me digress a minute to give an abstract of the ideas I put

together to devise models for these tests. If a program is hierarchical, the hierarchy can be traced to a base. At the base there will be certain basic abilities with which the learner must be equipped if he is to successfully complete the learning hierarchy. If such a program were completely effective, all students would achieve all intended elements in the program. In a program not completely effective, however, some of the students would in effect drop out at some point in the hierarchy. Those who drop out would tend to be low on measures of basic abilities relevant to the hierarchy, and the lower the basic ability, the earlier the dropout would be expected to occur. This dropout would be reflected in increasing correlations of basic ability with achievement at successive points in the hierarchy. The pattern of these correlation coefficients, then, could be used to judge the effectiveness of a structured program. A plot of correlation coefficients of basic ability with achievement at points upward in the

hierarchy (plotted against some distance in the hierarchy) would be expected to show near zero slope if the unit were effective. A slight positive slope would indicate an effective structured unit. A rapidly increasing set of correlations, indicating a high dropout rate, would be evidence of an ineffective unit.

Also, in a hierarchical program, achievement at a given point depends upon both basic ability and achievement at previous points. Basic ability would be important in predicting achievement early in the hierarchy, but it would become less important further in the hierarchy because achievement comes to depend more and more on achievement at the previous points and less and less on basic ability. Consequently, a regression analysis could be used to judge the extent to which a unit is hierarchical.

The third and final objective of the study was to institute an experiment which would provide the data (1) for measuring the effectiveness of the two units, (2) for

deciding if they were structured and unstructured as claimed, and, these conditions being met, (3) for examining some effects of structure on measures of achievement and transfer.

About two hundred fourth, fifth, and sixth graders were selected from schools which were participating in a larger study. Arithmetic ability was considered basic to the hierarchy of measurement concepts, so a measure of basic arithmetic ability was obtained on these students. Using the two modes of program, the three grade levels, and three levels of basic arithmetic ability, a three factor, mixed-model analysis of variance design was used to test assumptions regarding the effects of mode of unit upon achievement and upon transfer. A multiple linear regression analysis was done to give correlations and partial regression weights for determing the effectiveness of the units and for deciding the question of

structured and unstructured sequence.

Here is a brief summary of the results of the study:

1. No measurable difference in the effectiveness of the two units was found.

2. When grade and basic ability were not considered, mode of unit was found not to be a significant factor.

3. Grade level and ability level were found to be significant factors for both achievement and transfer. The student of high basic ability achieved higher than the student of low basic ability, and the older student seemed better able to transfer concepts.

4. There was a significant interaction between mode of program and basic ability when achievement was the criterion. The student of high basic ability achieved higher in the structured mode of program.

5. Both units were found to be effective.

6. The structured unit was found to be structured and the random version was definitely different.

What is more promising than these results, however - at this stage of investigation of the problem-is the potential worth of the models used for measuring the effectiveness and the extent of structure in the materials themselves. There are not enough available plots of correlation coefficients like those used in this study to allow one to judge what pattern indicates the most effective unit. Nor has there been enough done to decide what variable the coefficients should be plotted against so that the patterns can be mathematically described. On the basis of the results expected from the theory and those obtained in this study, this method of measuring the effectiveness of materials deserves further study. The questions relating to patterns indicative of effective units, appropriate independent variables for plots of correlation coefficients, and mathematical descriptions of the plotted patterns are the

first in need of attention. More attention should also be given to identification of relevant basic abilities for defined structures - a prerequisite to the meaningful study of effectiveness.

The success of the model used to determine the extent of structure in the two units was also encouraging. There was definitely a difference between the two units, and since the units were intended to be different in structure, this difference was attributed to structure. The patterns of partial regression coefficients, while generally as expected on the basis of the theory, are not as easily interpreted as the correlations used for determining effectiveness. The major weakness in this approach to identifying structure is the assumption of an independent set of measures for the linear regression model used. Any further attempt to use this model should account for the dependence of achievement at a given point upon achievement at preceeding points in the program.

The results of this study suggest that attempts to examine the effects of sequence on learning measures should at this time be abandoned in favor of attempts to write programs which conform to a defined pattern and to develop the appropriate tools for testing these programs. Programs, self-instructional or otherwise, could be written to conform to a specified model. Techniques could then be developed for testing these programs to ascertain if they are in fact written as defined - the models in this study are an exemplar. Having batteries of such well-defined programs, one would then be equipped with the requisite tools for answering questions about the type of program and effects of changes in the program on such measures as achievement, retention, and transfer.

The models used here proved promising only for units. The ideas are easily extended, however, to include courses, disciplines, and even a structured K-12 curriculum. The possibilities for short range, intermediate range, and long range studies are immense. They are exciting. They are of

great importance from the standpoint of making the educational enterprise more efficient and easier. This area of investigation offers the thinking researcher a challenge and promises him fruits for his labor.